# Knowledge Sharing Report-Milestone 3

RATCH-Australia

# Collinsville Solar Thermal Power Station

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## Contents

## Introduction

RATCH-Australia Corporation Limited (RAC), in partnership Transfield Infrastructure Pty Limited, and The University of Queensland (UQ), is undertaking all the preparatory development work to assess the viability of converting an existing 180MW coal fired power station to a 30MW hybrid solar thermal / gas power station at the Collinsville Power Station (CPS) in Queensland (the Project).

As part of the Project, RAC will also examine the feasibility of using Novatec's Supernova Linear Fresnel Solar Thermal technology to generate superheated steam to be supplied directly to a steam turbine to provide grid connected electricity. The dual-fuel boiler will also be designed to use natural gas to enhance grid reliability from the Project.

The Australian Government, through an Australian Renewable Energy Agency's (ARENA) Emerging Renewables Program Funding Agreement, is partly funding for the completion of the feasibility study.

This **Knowledge Sharing Report for Public Release** contains a summary of the learning's and knowledge gained during this phase of the Project, including information from the public release versions of the Design Study Report.

# Design Study Report

RAC is currently completing a competitive and commercially sensitive tender process to select the Engineering, Procurement and Construction (EPC) works supplier and the Operations and Maintenance (O&M) services supplier.

The Design Study Report summarises the technical and commercial works required to prepare the appropriate tender documentation for the EPC Contract and the O&M Contract.

The work includes the following sections:

- Technical specification and general arrangement drawings;
- Process flow diagrams, piping and instrumentation diagram (P&ID) and Heat balance diagrams;
- Draft engineering, procurement and construction contracts;
- Other tender documentation; and
- Gas supply design study.

The key non-commercially sensitive learnings gained during the development of the Design Study Report are outlined in the following sections.

# Technical Specifications

RAC's technical advisor has prepared a functional specification outlining the technical requirements for the EPC Contract including the associated technical drawings. The functional specification and the associated technical drawings are currently subject to a commercially sensitive competitive tender process.

## Learnings and Knowledge gained

The proposed hybrid solar thermal power plant with 100% fossil fuelled boiler support introduces some new challenges in relation to integration of the technologies as well as achieving a highly efficient and reliable power plant. The plant is to be designed for 25 years of operation and will be subject to daily operating cycles which will demand careful engineering of key items such as solar field receivers and piping, the steam turbine as well as the fossil fuelled boiler.

There will also be short term and frequent transients due to cloud cover that will require a rapid response from the fossil fuelled boiler and could produce significant transient stresses within the solar field.

All systems and equipment should be robust and able to accept all conceivable loadings and duties with minimal upset to operations or result in higher than normally expected maintenance.

## Steam & water quality requirements

The proper control of the water and steam quality throughout the boilers and power block is essential to the reliable operation of the plant. There are numerous guides or standards on the control of power plant water quality, but all modern standards have very similar requirements.

The key requirement is to provide pure steam to the turbine and IEC 61370, "Steam Turbines – Steam Purity", requires that the steam cation conductivity is less than 0.2 µS/cm. Babcock and Wilcox's "Steam" book expands on this requirement and advises that the total dissolved solids (TDS) at the inlet to the turbine should be less than 0.03 to 0.05 ppm (mg/l) and also states "If steam is to be superheated, a maximum steam dissolved solids limit must be imposed to avoid excessive deposition and corrosion of the superheater. This limit is generally 0.100 ppm or less".

The steam turbine requirement determines the quality of feed water required where spray desuperheating with boiler feed water is used as well the quality of water in the circulation system of boilers. Spray water quality should not exceed the turbine inlet steam quality requirements and IAPWS, "Volatile treatments for the steam-water circuits of fossil and combined cycle/HRSG power plants" recommends a feed cation conductivity of less than 0.1 µS/cm. For the boiler water, at approximately 130 bar, BS 2486, "Recommendations for treatment of water for steam boilers and water heaters", recommends a drum specific conductivity of (NB, not the same as cation conductivity) of less than 35 µS/cm which is approximately equivalent to 20 mg/l of salts.

The above requirements mean that spray water must be fully demineralised and that a condensate polisher after the condenser will be required. It also means that returning water from the boiler circulation circuits will not be acceptable as this will significantly compromise the spray water quality. It also means that steam separator efficiency must be extremely high to achieve the required turbine steam quality (in this case=99.8%). In a conventional boiler this is normally achieved by the use of suitable baffles or cyclones followed by demister pads or vane separators. It is suggested that a baffle plus vane separator design is the minimum to achieve this quality requirement.

## Evaporator circulation

The circulation flow through the evaporator field is determined by a number of constraints:

- The need to avoid approaching the mist flow regime in the evaporator. With mist flow, the heat transfer rate to the steam falls dramatically which leads to thermal fatigue problems in the tube. This is aggravated by the location of the bubbly to mist flow boundary constantly changing
- A need for sufficient flow at low loads to avoid excessive thermal stresses in the

entrance stratified or stratified/wavy regime.

- A need to ensure stability of flow through all evaporator tubes under transient conditions, such as clouds moving across the field.
- A higher circulation ratio allows a more reliable active flow balancing strategy.

### Spray desuperheater

Spray desuperheating should not be done at the inlet to a superheater as this will cause thermal stress problems at the inlet to the superheater as the boundary between two phase and single phase flow will be constantly changing with changes in flow parameters and energy input Desuperheating between stages also allows us to use well established cascade control strategy using both the outlet temperature from the first stage as well as the desuperheater outlet and last stage superheaters for excellent outlet temperature control during transient conditions.

it is suggested that the simplest way to achieve this is to remove two mirror bays half way down the superheater, bring the receiver tube down to near the mirror level and insert a venturi superheater at this level. The receiver tube would be returned to the inlet of the second stage superheater. Care should be taken to ensure that upstream and downstream installation requirements of the desuperheater are satisfied.

### Boiler

The proposed boiler will be a dual fuel boiler burning coal seam methane gas as the primary fuel and light oil with a sulphur content of up to 1%. If a single boiler is to be installed it is likely to have three or four burner registers to enable a turndown ratio of 25:1 to be achieved. The combustion fan will controlled with a variable speed drive as both an energy saving mechanism for partial load operation as well as allowing better low output air flow control than is available from damper control. The specification will emphasise efficiency and combustion efficiencies of greater than 95% are expected. To achieve the required efficiency a tubular air heater will reduce the gas temperature to approximately 125°C. When firing fuel oil, a steam to air pre-heater will be used to avoid flue gas corrosion of the tubular air heater. An automatic flue gas damper will also be installed to minimise the overnight heat losses.

The fast load rate change demanded will almost certainly mean that single drum boilers with fully welded construction and un-heated downcomers will be the technology required to reliably meet the duty required. The boiler will supply de-superheated steam to the solar field drum to enable a quick warm through of the solar field. The initial warm up steam will be at a low pressure and will have a controlled rate of increase to warm through the solar steam without inducing excessive stresses in heavy wall section such as headers and vessels. Once the solar field is up to pressure, the heating steam is isolated and superheated steam is supplied to the turbine inlet for normal, parallel operation of the boiler and solar field. The boiler has drum water conductivity control as for the solar field.

### Starting and stopping

The conditions on starting the solar field in the morning are dependent on the operating mode the previous day. If the previous day was a weekend or public holiday then as the solar input reduced then the system pressure will slide down and the field circulating pump delivery would reduce automatically. However, if there was boiler support on the previous day, the system pressure would be maintained even while the solar field output had reduced to zero.

### Starting

The fossil fuelled boiler will assist the solar field warm up by supplying steam at near saturated conditions into the field drum. The fossil fuelled steam supply would be via a pressure reducing and desuperheating valve which would have a sliding pressure set point to control the rate of heating from the boiler.

On starting of the solar field it is expected that the superheaters would be de-focused and the circulation pump started at a low flow prior to heat being accepted into the evaporator field. Depending on the operating conditions the previous day, this could mean admitting high temperature water to the field and would need to be done at a controlled rate. Once the field pressure is the same as the drum, then the mirrors may be focussed to generate steam and bring the system up to operating pressure. During this time steam will be passing through the superheater and then to a pressure reducing and desuperheating valve into the plant condenser. With an established flow of steam through the superheater, the mirrors can be controlled to generate superheated steam and warm through the steam lines prior to the turbine.

The fired boiler steam will then be delivered to the turbine for controlled warm up. Towards the end of this period the solar field will be up to pressure and temperature and then start to deliver steam to the turbine.

Depending on the operating mode, the fossil fuelled boiler may now be shut down into a hot standby mode.

### Stopping

During weekends and public holidays, the fossil fuelled boiler will be maintained at the solar field pressure by a small bleed of steam from the solar evaporator field. In the evening, the whole system pressure will decrease under turbine sliding pressure control until the system will shut down under low pressure conditions. At that point the fossil fuelled boiler will be isolated to conserve the heat in the boiler. This will also mean an earlier start the next morning to bring the boiler up to pressure.

During normal weekdays, the fossil fuelled boiler will maintain the plant at full pressure until required to shutdown at night. The boiler will then be isolated to conserve the energy in the boiler. In the evening, the solar field will have stopped and should be isolated so that cooling of the field does not reduce the heat the solar field drum.

### Overnight

A small gland steam flow is required to avoid air ingress into the turbine and condenser. If the boiler has been shut down at high pressure, then the boiler is capable of delivering the required gland steam flow from the drum via a pressure reducing valve.

If the system is shutdown at a low pressure, then there may not be sufficient energy stored in the boiler to provide the necessary gland steam. If this is the case, a very small gas fired boiler may be needed to supplement the main boiler flashed steam delivery.

## Draft EPC and O&M Contracts

RAC and their legal advisors have prepared a draft EPC Contact and O&M Contract for the Project. The purpose of these contracts is to define the requirements that allow the EPC Contractor and O&M Contractor to submit offers to RAC for the respective bodies of work.

- The EPC Contract includes the engineering, procurement, construction, testing, commissioning and completion of the Project. The EPC Contractor is required to provide all plant, materials, equipment and documents specified in the EPC Contract and all goods, consumables and services, whether permanent or temporary, required for the works.
- The services under the O&M Contract comprise the operation and maintenance of the Project for at least the initial five years following commercial operation.

These documents are based on market standards and have been developed to address the perceived bankability requirements of potential lenders for the Project.

### Learnings and Knowledge gained

A key requirement for a successful and bankable EPC and O&M Contract is the risk allocation between the technology suppliers, EPC and O&M contractors and the owner of the project.

As solar-thermal is an emerging technology, the technology owners request more flexibility and time to remedy in the terms of the contract than would be incorporated in the contractual arrangements traditionally applied to established technologies. In addition, as this technology has not been widely applied in an Australian environment, the technology provider requires time and assistance to familiarise themselves with the local legal, commercial and technical environment.

The EPC and O&M providers, who are not familiar with the emerging technology or technology provider, require additional time to complete sufficient due diligence on the technology providers prior to submitting proposals. The limited understanding of solar-gas hybrid technologies in Australia exacerbates this issue.

These issues highlight the importance of a proactive and comprehensive stakeholder engagement process for emerging technologies throughout the tendering process, an innovative approach to contractual terms and the allowance of sufficient time within the project schedule to address these issues.

RAC note that the success of the tender process is yet to be tested within the market.

## Tender Documentation

The selection of the EPC Contractor and O&M Contractor will be completed through a formal competitive tender process. The request for tender documents, i.e. other tender documentation, prepared for the formal tender process consists of an invitation to tender and instructions to tenderers.

The invitation to tender letter provides an introduction to the Project, an overview of the tender process, confidentiality requirements and a form of acknowledgement. Once interested tenderers return the form of acknowledgement, they are supplied with the instructions to tenderers and remaining tender documentation.

### Learnings and Knowledge gained

To support the learning identified during the Draft EPC and O&M contract section above, a formal structure and clearly articulated tender process, incorporating sufficient time for a comprehensive stakeholder engagement and the negotiations of contractual terms is imperative for the success of the tendering process, and meeting project schedules.

RAC note that the success of the tender process is yet to be tested within the market.

## Gas Supply Design Study

The planned development of a 30 MW hybrid solar thermal and gas power station at CPS has led to the investigation of a pipeline system to transfer coal seam gas (CSG) to the site. The size and pressure of the proposed gas pipeline and associated storage requirements are investigated in this Gas Supply Design Study.

### Learnings and Knowledge gained

For this study it is assumed that the hybrid solar thermal plant will be capable of supplying baseload power to the grid during predetermined operating times. This means the power output from the plant must remain steady throughout the predefined operating periods. Effectively, the gas fired boiler supports the operation during periods of varying solar input.

The expected plant operating regime is as follows:

- Operation for 15 hours per day, 7am until 10pm, on weekdays (Monday-Friday)
- Running on solar energy only over the weekends
- On weekends, burning gas for up to 3 hours each day as required to manage gas consumption.

The available solar energy will peak during the day, and periodically fluctuate with the prevailing cloud cover. Gas is consumed by the solar thermal hybrid power station during the expected operating period when there is insufficient solar energy generated by the solar boiler, i.e. the preferred source of power is solar thermal energy supplemented by gas as required.

A gas usage profile has been generated by a bespoke model, based on the above running regime and the weather data for a typical year. Due to the unstable and relatively unpredictable nature of the solar resource, the gas consumption of the plant is similarly hard to predict and varies dramatically over time.

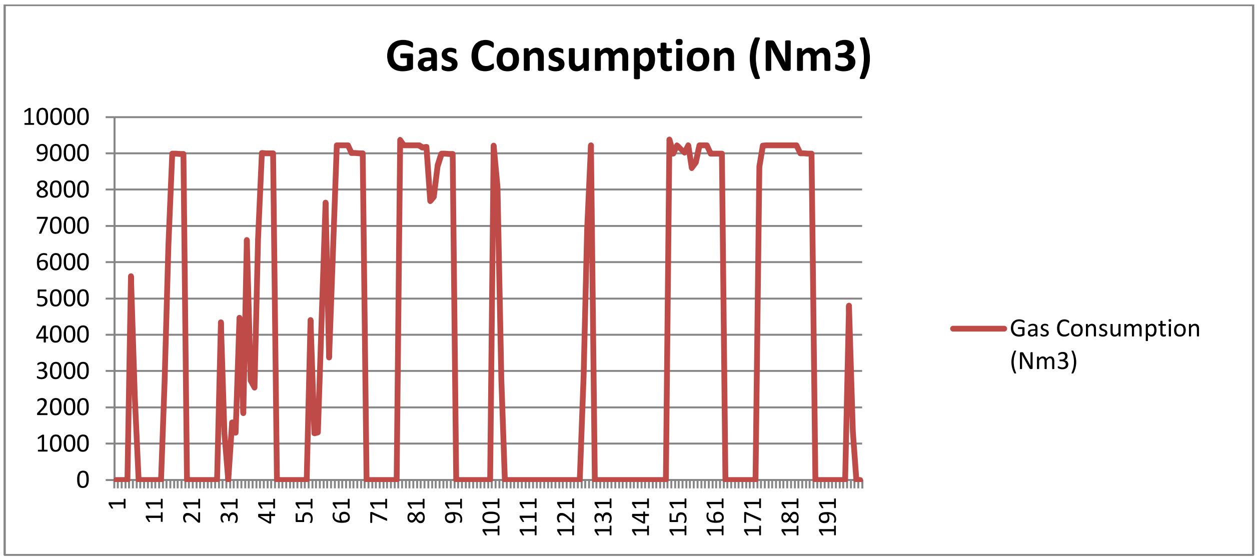


**Figure 1: Typical expected gas consumption of the plant over a 200 hour period.**

Figure 1 above shows a snapshot of the modelled gas consumption over time. Note the large fluctuations in gas consumption that can vary from zero to close to 100% demand in the space of only a few hours. It can also be seen from the graph that total gas consumption varies from day to day so that average daily gas consumption is likely to vary significantly. Further, extended periods of generally cloudy or generally sunny weather, and annual seasonal changes, are likely to result in significant variance in average gas consumption over weeks and even over months.

Detailed review of the historic weather fluctuations indicated that the required volume of storage was driven primarily by the extended periods of high solar energy, with the daily operating profile having a secondary affect.

Ideally, the supply of gas to the proposed pipeline would be equally matched with consumption, resulting in no requirement for storage. However, gas supply contracts are based on a steady supply. It is noted that it is possible to have some active management of gas supplies, but the extent of this control and the commercial implications are currently unclear.